# Controlling Technology with the Mind

## *Mapping the Mind*

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## introduction

Did you know that the human brain contains approximately 86 billion neurons? These cells act as information messengers, communicating through electrochemical signals that create measurable electrical patterns when groups of neurons fire together (NINDS, 2023). By detecting and interpreting these patterns, Brain–Computer Interfaces (BCIs) make it possible to transform thoughts into actions.

As a result, BCIs have significant real-world applications, particularly in rehabilitation, where they enable people with neurological disorders or paralysis to regain independence and interact with their environment.

## scientific explanation

A BCI is a system that enables direct communication between the brain and an external device by using neural signals. Neurons (figure 1) communicate using action potentials, which are rapid changes in membrane potential caused by ion exchange ($Na^+$ and $K^+$ ions). This allows brain activity to be associated with intention, such as thinking about moving a hand can be translated into commands that can control machines like computers or robotic limbs.

There are two types of BCIs, non-invasive (figure 2) and invasive (figure 3). Non-invasive BCIs is where electrodes, a type of sensor, are placed outside of the skull. It is safe but also low resolution. Meanwhile, invasive BCIs, is when implants like Neuralink are placed into the brain. They are high precision but there are surgical risks.

Most non-invasive BCIs, which are BCIs with electrodes on the outside of the skull, use Electroencephalography (EEG) where:

- Electrodes placed on the scalp detect voltage fluctuations
- Signals represent summed activity of neurons on the outer surface of the brain
- Brain waves are categorised into frequency bands of delta, theta, alpha and beta. (figure 4)

EEG signals are low amplitude and noisy, requiring amplification and filtering

BCIs rely on advanced computer steps:

1. Signal Acquisition – EEG electrodes capture raw signals
2. Preprocessing – Noise removal (e.g., filtering eye blinks)
3. Feature Extraction – Identifying relevant patterns (e.g., motor imagery signals)
4. Classification – Machine map signals to intentions
5. Output Translation – Commands sent to external devices

figure #1

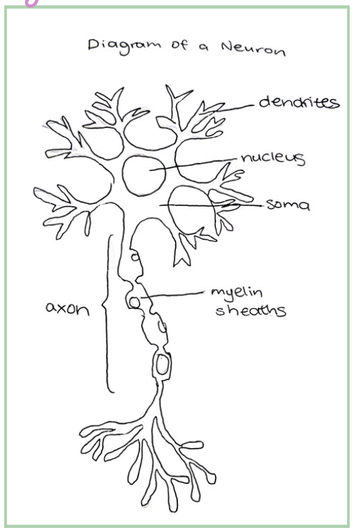



figure #2

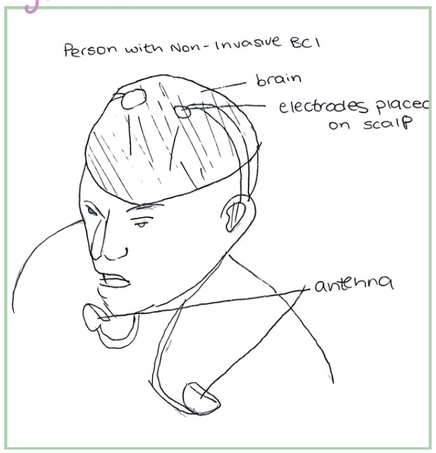



figure #3

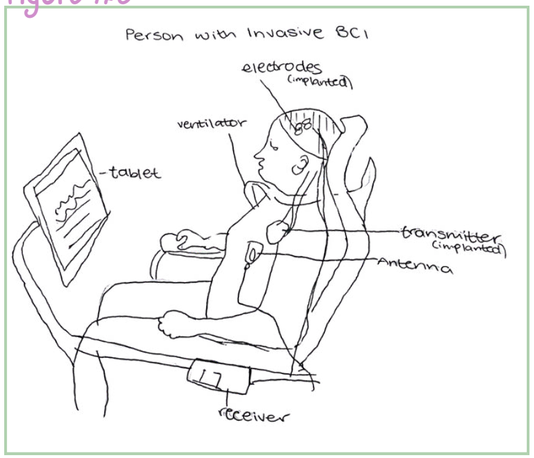
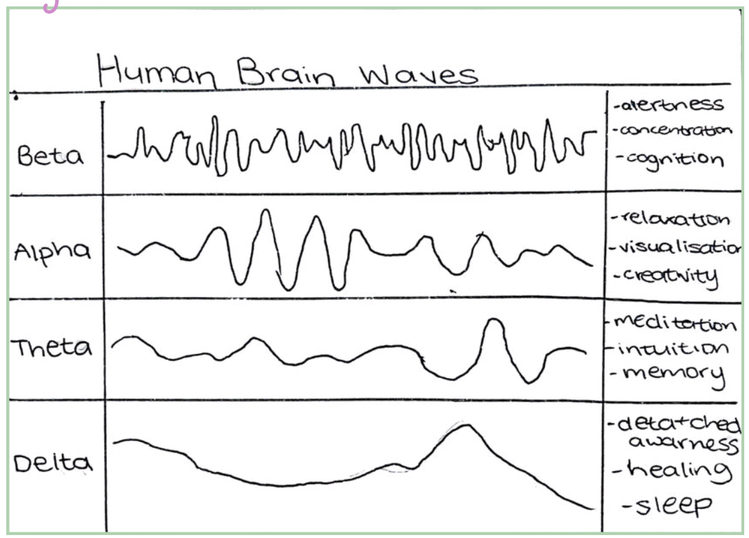



figure #4




## real-world relevance

Brain–Computer Interfaces can create significant real-world impacts by converting neural activity associated with intention into physical actions. This allows thoughts to directly control external devices, leading to major advances in assistive technology. For example, people with paralysis can use BCIs to control robotic limbs to perform everyday tasks, while people with locked-in syndrome can communicate by selecting letters using only brain activity.

BCIs also advances neuroscience by helping researchers map how brain signals relate to movement and cognition, improving understanding of neurological disorders and supporting targeted therapies.

In the future, BCIs may integrate with artificial intelligence to improve how accurately thoughts are translated into actions.

## bibliography & acknowledgements

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